

- [54] HIGH PERFORMANCE TRANSDUCER
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- [73] Assignee: **said Bradley, by said Ast**
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- [52] U.S. Cl. **338/32 R, 323/94 H, 338/32 H**
- [51] Int. Cl. **H01c 7/16**
- [58] Field of Search **338/32 R, 32 H; 323/94 H; 324/45, 46; 335/1; 340/65 L**

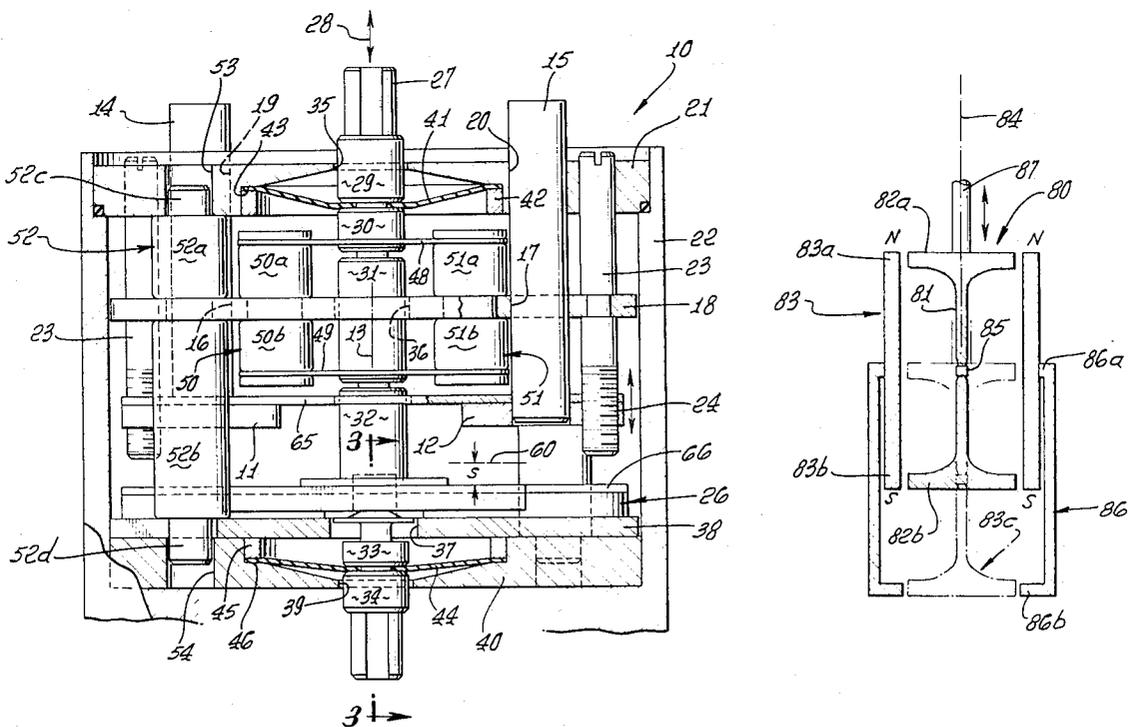
- [56] **References Cited**
- UNITED STATES PATENTS**

| | | | |
|-----------|--------|--------------------|----------|
| 3,676,828 | 7/1972 | Masuda et al. | 338/32 H |
| 3,680,026 | 7/1972 | Masuda et al. | 323/94 H |
| 3,783,430 | 1/1974 | Nishiba | 338/32 H |

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- [57] **ABSTRACT**
- An "all purpose" transducer is characterized in that a small input displacement is productive of a desirably large change in an electrical parameter.

19 Claims, 7 Drawing Figures



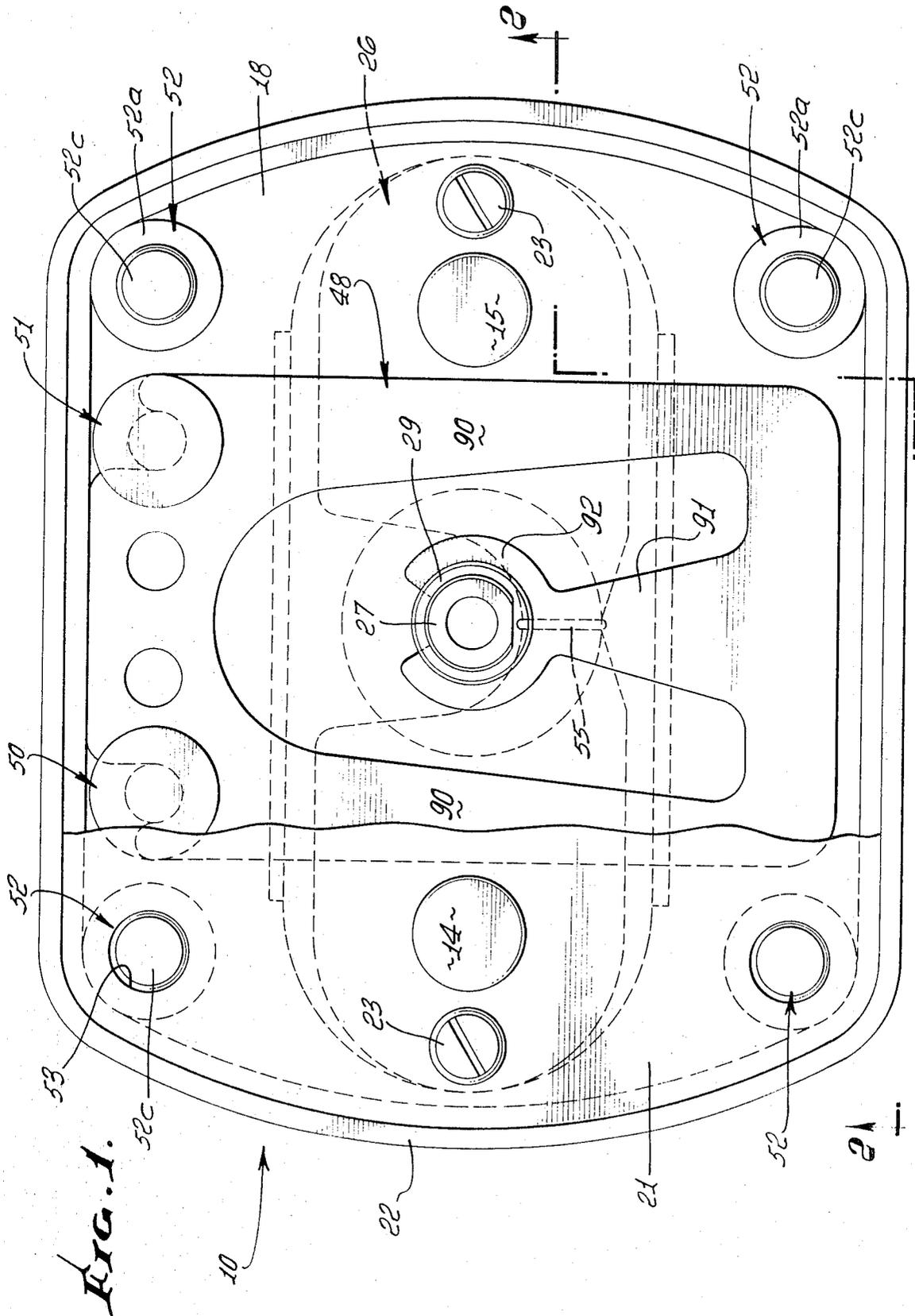


FIG. 2.

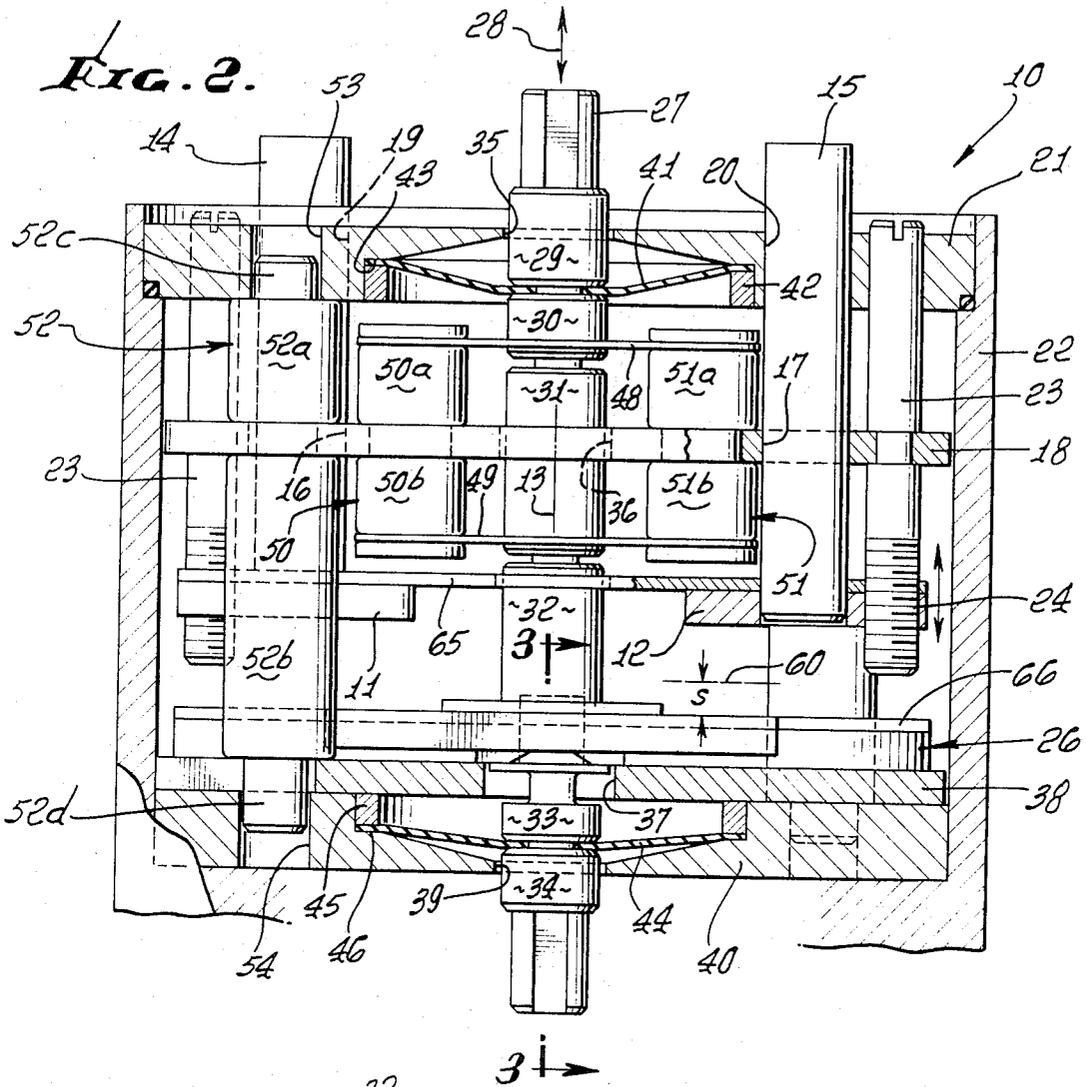


FIG. 3.

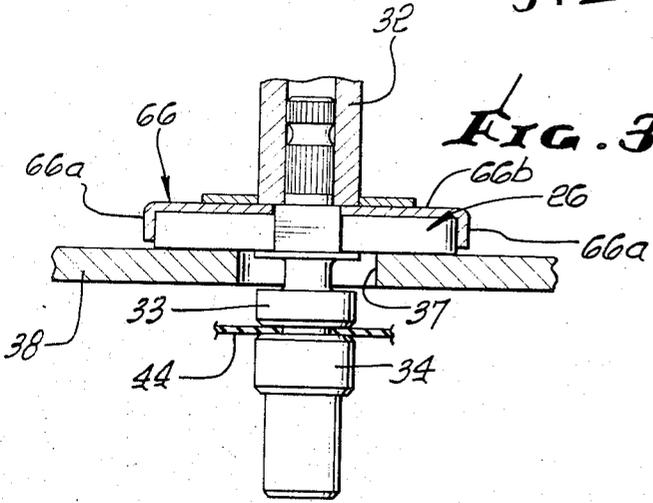


FIG. 4.

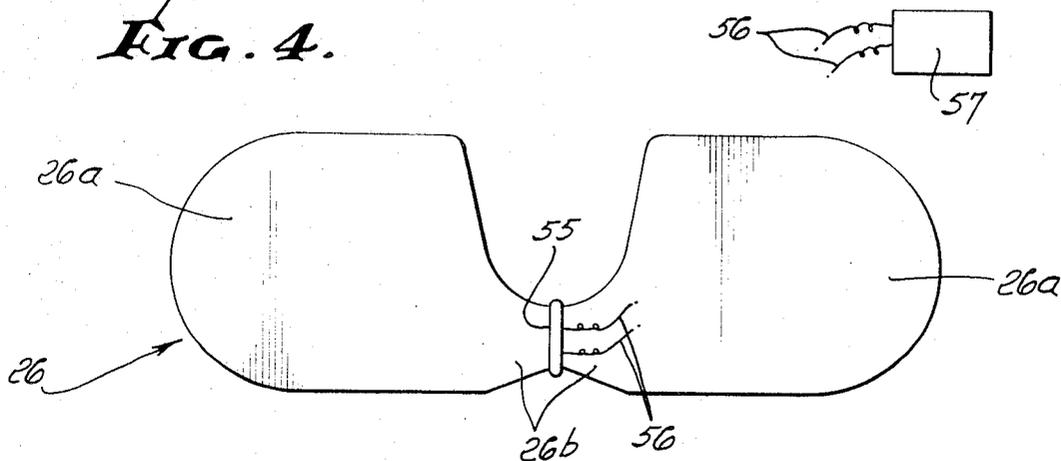


FIG. 5.

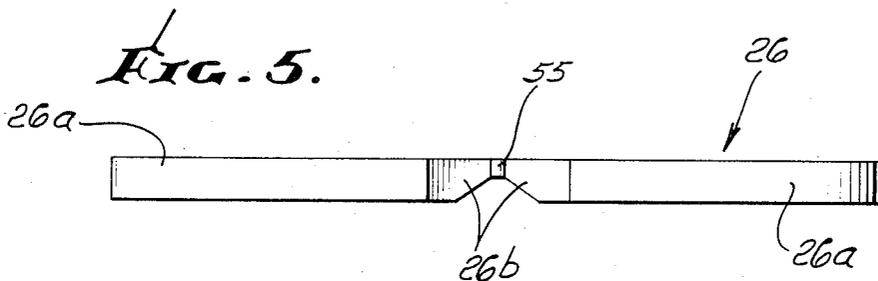


FIG. 6.

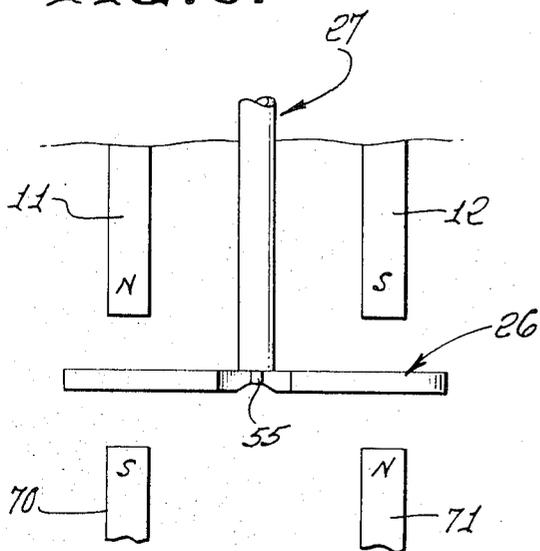
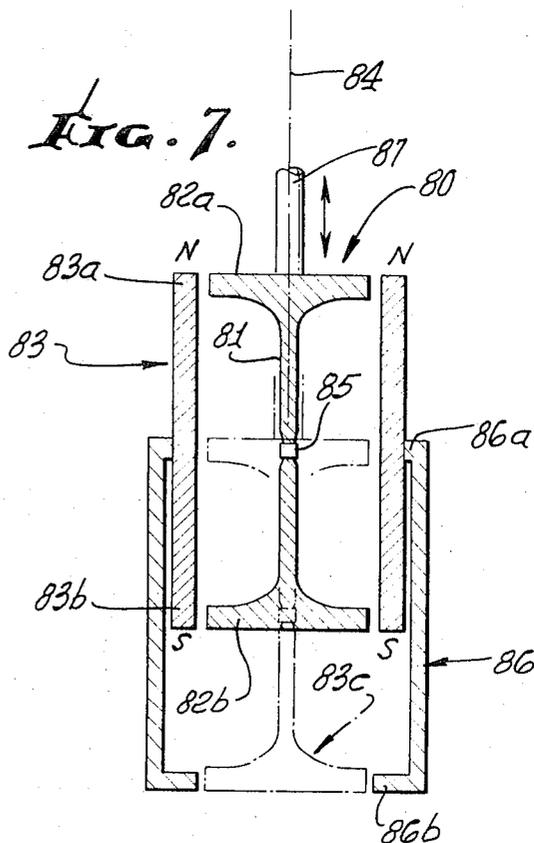


FIG. 7.



HIGH PERFORMANCE TRANSDUCER

BACKGROUND OF THE INVENTION

This invention relates generally to transducers, and more particularly concerns the provision of an "all-purpose" transducer wherein a small input displacement is productive of a desirably large change in an electrical parameter.

There is a need for simple and accurate transducers of the "all-purpose" type, as referred to above, and which are further characterized by high resolution and output accuracy, for small input displacements of the order of 0.100 inches and less. One desirably simple solution to this problem embodies the use of a resistance material that is sensitive to changes in a magnetic field, i.e. so-called magnetoresistive materials; however, magnetic fields tend to be non-linear and to spread which introduces the further problem of how to effect a maximum and controlled change in flux or field intensity for input displacements of less than 0.100 inches. Additional problems include the effects of temperature change upon the materials of the transducer to produce output non-linearities, and non-linearity arising from magnetic attraction of the poles upon the armature.

SUMMARY OF THE INVENTION

It is a major object of the invention to provide an all purpose transducer overcoming the above as well as other problems encountered in this field. Basically, the transducer is embodied in the combination that includes: spaced poles of opposite polarity; a magnetic flux transmitting armature relatively movable toward and away from the poles to increase and decrease, respectively, the flux transmission by the armature; a flux responsive element carried by the armature to pass the flux, and characterized as having electrical impedance that varies as a function of flux intensity; and the armature having an overall range of movement between limits at one of which flux transmission by the element is at a maximum, and there being means cooperating with the armature to cause the flux passed by the element to drop to near zero when the armature is at the other of its limits. As will appear, such means may include a flux shorting bar extending laterally in proximate and generally parallel relation to the armature throughout its range of movement; and alternatively, such means may comprise auxiliary magnetic poles at the side of the armature opposite the first mentioned poles, and being of opposite polarities which are reversed in relation to the polarities of the first mentioned poles.

Additional objects include the provision of an armature which has laterally spaced, relatively wide portions in alignment with the poles, and reduced width portions between the wide portions, with the flux responsive element located between the flux concentrating and dif-fusing portions which are spaced apart; the provision of flux by-passing means extending between the poles and a flux by-passing member carried adjacent the armature, the arrangement being such as to compensate the output of the flux responsive element for temperature induced changes in impedance; the provision of a shaft carrying the armature and flat spring means supporting the shaft for longitudinal movement in such manner as to overcome magnetic attraction between the armature, and both poles and shorting bar; the ability to read outputs on inexpensive multimeters or voltmeters; and

the provision of additional improvements in construction and arrangement as will appear.

These and other objects and advantages as well as the details of an illustrative embodiment, will be more fully understood from the following description and drawings, in which:

DRAWING DESCRIPTION

FIG. 1 is a plan view section taken through one preferred embodiment of the invention;

FIG. 2 is a section taken in elevation on lines 2—2 of FIG. 1 but broken away in certain areas;

FIG. 3 is a section taken in elevation on lines 3—3 of FIG. 2;

FIG. 4 is a plan view of the armature employed in FIGS. 1—3;

FIG. 5 is a side elevation of the FIG. 4 armature;

FIG. 6 is a schematic showing of an alternate form of the invention; and

FIG. 7 is a section in elevation showing another modification.

DETAILED DESCRIPTION

The illustrated transducer 10 includes magnetic poles 11 and 12 of opposite polarity, spaced at opposite sides of a longitudinal axis 13. The poles may for example be carried on elongated magnets 14 and 15 which are slidably guided in bores 16 and 17 in bulkhead 18, and in bores 19 and 20 in an end cap 21 for the housing 22. End cap 21 may be suitable attached to the housing, and may guide a pair of adjustment fasteners or screws 23 which have threaded connection at 24 with the pole pieces, and retained by slots in bulkhead 18. Accordingly, means is provided whereby the pole pieces may be adjustably shifted longitudinally, i.e. in response to rotation of the screws 23, for calibration purposes as will appear.

The transducer also includes a magnetic flux transmitting armature relatively movable longitudinally toward and away from the poles to increase and decrease, respectively, the flux transmission by the armature. In the example, transversely extending armature 26 is advantageously carried by longitudinally extending shaft 27, to which input motion may be applied as indicated by arrows 28. The shaft may include multiple cylindrical enlargements indicated at 29—34, and may typically pass through bore 35 in end cap 21, bore 36 in bulkhead 18, bore 37 in shorting bar 38, and bore 39 in opposite end cap 40. A flexible diaphragm 41 has its inner periphery clamped between enlargements 29 and 30 and its outer periphery held by retainer ring 42 to the upper cap annular shoulder 43, whereby the diaphragm seals off between the shaft and cap 21 at the upper side of the armature 26. Likewise, a flexible diaphragm 44 has its inner periphery clamped between shaft enlargements 33 and 34, and its outer periphery held by retainer ring 45 against lower cap annular shoulder 46, whereby the lower diaphragm seals off between the shaft and cap 40 at the lower side of the armature 26, the shaft remaining capable of longitudinal movement.

The shaft may advantageously be carried for movement by spring means located within the housing. In the example, parallel flat beam springs 48 and 49 are centrally connected with the shaft enlargements 30 and 31, respectively, and they extend transversely from like supports 50 and 51 located at one side of the shaft.

Each beam spring includes arms 90 and 91, and a center section 92. The supports are carried by the bulkhead 18, and extend above and below the latter at 50a and 50b, and at 51a and 51b, for attachment to the beam springs, as shown. The transverse bulkhead is in turn carried by longitudinal supports 52, which include enlarged sections 52a and 52b respectively extending between the bulkhead 18 and cap 21, and between the bulkhead 18 and the shorting bar 38. The supports 52 have reduced pilot terminals at 52c and 52d receivable within bores 53 and 54 in the caps 21 and 40 facilitating assembly and disassembly of the transducer.

The transducer also includes a flux responsive element carried by the armature to pass the flux transmitted transversely through the armature, that element characterized as having electrical impedance which varies as a function of the intensity of the flux passed by the element. Certain examples of such elements are those described in the article, "Use of Magnetoresistors in Measuring Non-Electric Quantities" published in Siemens Electronic Components Bulletin, IV (1969) No. 1 by Ulrich Eberhardt and Walter Oehler, other examples being of other type impedance elements. In FIGS. 1-5, the illustrated armature 26 extends laterally and has two, like relatively wide portions 26a movable longitudinally in alignment with the poles 11 and 12, and two, like, relatively narrow portions 26b intermediate portions 26a. The magnetoresistor 55 is located directly between portions 26b to pass all the flux passing between these flux concentrating and diffusing portions. Leads 56 extend from element 55 to suitable circuitry indicated schematically at 57 in FIG. 4 for applying voltage to the element 55 and for detecting a change in current resulting from a change in resistance of that element. Such change in resistance is, of course, a direct result of longitudinal movement of the armature toward or away from the pole pieces 11 and 12. The invention is particularly well adapted to produce highly linear read-outs as a function of small shaft or armature longitudinal displacement; i.e., good resolution and accuracy are obtained for small displacements (less than about 0.100 inch) can be obtained, although the invention is not restricted in its application to any particular input displacements.

As a result of the transducer configuration, the magnetoresistive element is enabled to characteristically undergo a resistance change of at least 400 percent as the armature is moved through its range of motion, indicated by the dimension "s" in FIG. 2. Such a large resistance change enables the transducer to be used for measurements that are only a small fraction of full displacement and still retain very high accuracy. At the upper limit designated by broken line 60, the flux transmitted by the element 55 is at a maximum, whereas at the lower limit indicated by the solid line position of the armature in FIG. 2, means is provided to cooperate with the armature to cause the flux passed by the element to drop to zero, or near zero. In the example, such means comprises a flux shorting bar which may take the form of the bulkhead 38 previously described. The latter extends laterally in proximate and generally parallel relation to the armature, being retained between cap 40 and support enlargements or sleeves 52b. Further, the shorting bar is characterized as having high flux permeability, and may for example consist of a suitable magnetic alloy.

It should be noted that the forces of attraction between the armature and both the permanent magnet poles 11 and 12 and the bulkhead 38 (shorting bar) may be balanced out by the proper placement of spring supports 48 and 49.

A further feature of the invention has to do with overcoming the problem of variation in output of the magnetoresistive element as a function of temperature change. Such variation results from the usual variation in impedance of magnetically sensitive materials. To counteract this effect, and to maintain linearity, means is provided to controllably and quantitatively by-pass flux as a function of temperature. In the example, such means may with unusual advantage include a magnetic shunt member 65 extending transversely between the poles 11 and 12 at the sides thereof opposite the armature, and also a magnetic flux shunting support 66 for the armature 26. Support 66 is shown in FIG. 3 to have channel shape to embrace the armature between support arms 66a to extend at 66b across the top side of the armature, i.e. between the armature and poles 11 and 12. The members 65 and 66 may consist of a material whose flux permeability changes as the temperature increases. The members 65 and 66 may for example consist of a magnetic alloy. As a result, the variation in output of the element 55 as a function of temperature change may be eliminated, as for example where about half the temperature compensation is effected by member 65, and about half the compensation is effected by support 66.

In FIGS. 1 and 2, the housing interior can be filled with liquid to eliminate or reduce the effects of gravity on the moving elements.

Referring to the modification seen in FIG. 6, an auxiliary pair of poles 70 and 71 replaces the shorting bar or bulkhead 38, the other elements remaining the same as in FIGS. 1-5. Pole 70 is of opposite polarity to pole 11, and pole 71 is of opposite polarity to pole 12. At a certain location between the two sets of poles, the flux transmitted laterally through the armature and the element 55 approaches or reaches zero, corresponding to the position of the armature adjacent the shorting bar 38 in FIG. 2.

In the modification seen in FIG. 7, the armature 80 comprising an elongated stem 81 having heads 82a and 82b at opposite ends thereof. The poles of opposite polarity are indicated at 83a and 83b as spaced apart longitudinally and on a tubular magnetic member 83 which extends in coaxial relation with the armature, the central axis indicated at 84. A flux responsive element 85 is carried by the armature to pass flux, the element characterized as having electrical impedance which varies as a function of the intensity of the flux passed by the element. Thus, the latter corresponds to element 55 described above.

The armature is endwise movable as by shaft 84, or other structure, relative to member 83, it being understood that one or the other of 80 and 83 is movable relative to the other, and longitudinally. The overall range of armature movement is between limits at one of which (the solid line position shown) the flux transmission by the elements 85 is at a maximum; the other limit is indicated by the broken line armature position 83c, at which flux transmission by element 85 is at a minimum.

Means cooperating with the armature to cause the flux passed by the element to drop to near zero at posi-

tion 83c comprises a flux shorting bar 86 having for example the form of a tube or cylinder receiving portions of the armature and magnetic member 83. Note that the head 82a of the armature, when in armature position 83c, is approximately mid-way between poles 83a and 83b, and lies radially inwardly of the annular end 86a of the shorting bar 86; likewise, head 82b of the armature then lies radially inwardly of the annular end 86b of the bar 86.

The elements 83 and 86 need not be tubular, and can be confined at one side of the armature.

I claim:

1. In a transducer for providing an electrical output that varies as a function of a displacement input, the combination comprising

- a. spaced poles of opposite polarity,
- b. a magnetic flux transmitting armature relatively movable longitudinally toward and away from the poles to increase and decrease, respectively, the flux transmission by the armature,
- c. a flux responsive element carried by the armature to pass said flux, said element characterized as having electrical impedance which varies as a function of the intensity of the flux passed by the element, and
- d. the armature having an overall range of movement between limits at one of which the flux transmission by the element is at a maximum, and there being means cooperating with the armature to cause the flux passed by said element to drop to near zero when the armature is at the other of said limits.

2. The combination of claim 1 in which the element is magnetoresistive and characterized as undergoing a resistance change of at least 400 per cent as the armature moves between said limits.

3. The combination of claim 1 wherein the armature extends laterally and has relatively wide portions movable longitudinally in alignment with said poles, and relatively narrow portions intermediate said wide portions, said element being located between said relatively narrow portions.

4. The combination of claim 1 including flux by-passing means extending between the poles to quantitatively by-pass flux therebetween as a function of temperature.

5. The combination of claim 1 including flux by-passing means extending adjacent the armature to quantitatively by-pass flux therebetween as a function of temperature.

6. The combination of claim 1 wherein said means includes a flux shorting bar extending laterally in proximate and generally parallel relation to the armature throughout said range of armature movement.

7. The combination of claim 1 including a longitudinally movable input member operatively connected with the armature.

8. The combination of claim 1 wherein said means includes auxiliary magnetic poles at the side of the armature opposite said first mentioned poles, and longitudinally spaced therefrom.

9. The combination of claim 1 including means for adjustably shifting the poles longitudinally.

10. The combination of claim 7 including a longitudinally extending shaft carrying the armature and spring means supporting the shaft for said longitudinal movement, the spring means balancing out the magnetic attraction forces at both extremes of shaft travel.

11. The combination of claim 10 including a housing enclosing the poles, armature and spring means, the shaft having an input motion receiving end portion accessible from the exterior of the housing, the spring means supported by the housing.

12. The combination of claim 1 wherein said range of movement is less than about 0.100 inch.

13. The combination of claim 1 wherein said means includes third and fourth magnetic poles at the side of the armature opposite said first mentioned poles, said third and fourth poles being of opposite polarities which are reversed in relation to the polarities of the first mentioned poles.

14. The combination of claim 11 including liquid substantially filling the interior of said housing.

15. The combination of claim 1 wherein said poles of opposite polarity are spaced apart generally laterally.

16. The combination of claim 1 wherein said poles of opposite polarity are spaced apart generally longitudinally.

17. The combination of claim 16 wherein said poles are on a tubular member which has a longitudinally extending axis.

18. The combination of claim 17 wherein said means includes a flux shorting bar extending generally longitudinally, the armature also extending generally longitudinally.

19. The combination of claim 18 wherein the flux shorting bar is tubular and receives at least portions of the armature and said tubular member.

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